Quantum Physics and the Identity of Indiscernibles + Applications
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1. Introduction

In the philosophical literature the notions of identity, individuality and indistinguishability have received a great deal of attention. In this paper we shall discuss how these notions have been treated by quantum physicists, and discuss the relevance of this to the traditional philosophical arguments about these matters.

Identity is a relation that may exist between items that figure in a particular area of discourse. Item a is identical with item b, symbolically a = b, means informally that there are not in reality two distinct items at all, but only one item, which may be referred to indifferently as a or b. We use 'item' here as a neutral word that comprehends both universals and particulars. Particulars that exist in the physical world ~~(Popper's world 1 if you like)~~ we shall refer to as physical individuals or just individuals for short.* Physical individuals are to be distinguished then from other sorts of particular such as events or states of affairs that may be said to occur or obtain rather than to exist. ~~Initially we shall confine our discussion to individuals~~ which have more or less well-defined spatial locations. # In the philosophical literature ~~such~~ individuals are often referred to as 'things'.

What confers particularity, or individuality as we shall call it, on physical individuals? This raises the fundamental problem of how the particular is related to the universal, of how an individual is related to its attributes. Is it possible for two (non-identical) individuals to have all the same attributes in common, that is to say to be indistinguishable (indiscernible in traditional philosophical terminology). Leibniz famously claimed that this was not possible, his Principle of the Identity of Indiscernibles (PII).

* Monton The existence of such individuals we take to imply their persistence through time. They are continuants.

question II, provided the attributes do not involve intentional contexts.

(1) Should we include relations (non-monadic predicates)?

* , on the grounds that such an attribute already presuppose individuation and hence cannot be used to account for it, is not a genuine monadic predicate but expresses a relation of, & to which relation (of identity) is also satisfied by 2.

In terms of second-order logic with equality PII states

$$\forall F\ (F(\underline{a}) \leftrightarrow F(\underline{b})) \rightarrow \underline{a} = \underline{b} \qquad (1)$$

where a and b are any two individual constants and F is a variable ranging over the possible attributes of these individuals.

(1) should be contrasted with the Principle of the Indiscernability of Identicals

$$(\underline{a} = \underline{b}) \rightarrow \forall F(F(\underline{a}) \leftrightarrow F(\underline{b})) \qquad (2)$$

(2) is uncontroversial. If two individuals are identical so there is in reality just one individual, then there can only be one set of truly predicated attributes. But (1) has led to a great deal of argument. What sort of attributes should be included in the range of the variable F? If we include the attribute being indentical with a, which is certainly true of a, then (1) is a theorem of second-order logic. But suppose we rule out trivializations of PII of this sort, then we can still distinguish a strong and weak version of PII.

Strong version : F includes properties of spatio-temporal location.

Weak version : F excludes properties of spatio-temporal location.

Leibniz himself apparently subscribed to the weak version of PII. Hence his interest in searching for indistinguishable leaves in the Herrenhausen Gardens in Hanover.[2] If we subscribe to PII in the strong version this raises important questions concerning what we are to understand by spatio-temporal location. In a relational theory of space and time a circularity develops. Individuation of material objects -- leaves, tables, chairs -- involves specifying their location in space and time. But this location involves their relations with other physical individuals. Absolute theories of space and time avoid this circularity but at the expense of requiring an account of what it is that confers individuality on the points of space, and instants of time.

Eventually

* despite the problems just opened to us (which may threaten to reintroduce TI for ports & space!)

PII seeks to reduce the particular to the universal, the individual to a bundle of properties or attributes. But many philosophers have argued that such a reduction is not possible, that individuals involve something over and above their attributes, that confers individuation in an essential and unanalyzable way. This is to go the way of the Lockean substratum, the unknowable 'something' that attributes 'attach' to. If an individual acquires its individuality by something that transcends its attributes we shall say that it exhibits transcendental individuality, TI for short. Modern analytical philosophy has not taken kindly to TI. Physical individuals are usually regarded as being individuated by their location in space and time, and the problem of reidentification, of the grounds for claiming that an individual b at time t is the same individual as the individual a at an earlier time t', is solved in terms of the spatio-temporal continuity of the trajectory joining the location of a at time t' and the location of b at time t. The proponents of TI might agree that spatio-temporal continuity (S-T) is what allows us to infer a reidentification across an interval of time, but they would claim that it is the persistent TI, that, ontologically speaking, confers the reidentifiability.

Before turning from philosophy to physics there is the important notion of relative identity that we would like to refer to briefly. Instead of saying boldly 'a at time t' is the same individual as b at time t ', let us make the relative identity claim 'a at time t' is the same S as b is at time t ', for some sortal predicate S. This is the kind of reidentification that is involved for 'processes' rather than 'things' and will arise in our later discussion as crucial to the distinction between waves and particles in physics.

* Smeka (In what follows we assume for simplicity that all observables under discussion have a discrete spectrum).

having the same intrinsic properties such as mass, spin and charge, but